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ABSTRACT

This study investigated the meanings and ideas held and questions asked by children (ages 7-14) about floating and sinking (in water). Data were collected from interviews using "interview-about-instances" (IAI) cards (included in an appendix) and 10 objects which either floated or sank. Additional data were collected from classroom surveys and from lessons designed to elicit student questions and answers about the topic. Student responses are presented, discussed, and analyzed in separate sections addressing: (1) children's meanings for the work "floating"; (2) children's explanations of why things float or sink; (3) ideas relating to the effect on floating material if the object is changed or the depth of displacement of water is altered; and (4) children's questions about floating and sinking. Responses are categorized within each section by major patterns noted during analyses. The interviews revealed that different children attached different meanings to the word floating, which varied with context (such as observing real objects in water as opposed to viewing line drawings) and that these meanings in some cases differed from those of scientists. In addition, children had a range of views about why some things floated while others sank. Implications for science instruction based on these and other findings are noted. (JN)

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STUDENTS' VIEWS OF FLOATING & SINKING

SE 045 318

Science Education Research Unit
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Working Paper No. 116

STUDENTS' VIEWS OF FLOATING AND SINKING

Fred Biddulph

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INTRODUCTION

Floating and sinking (in water) is a topic which Harlen and Osborne (1983) proposed might be suitable for study by children at the primary school level. Several investigations of children's explanations of flotation (Inhelder and Piaget, 1958; Laurendau and Pinard - cited by Good, 1977; Rowell and Dawson, 1977; Von Pfuhl Rodrigues, 1980) indicate that children seldom fully understand the principle of flotation before at least age 13 or 14 years. This finding might suggest that the topic would be best left until the secondary level but this need not be so. There are several notions that contribute to a full understanding of flotation, and if children acquire misleading ideas during their primary school years then their later development of full understanding could be impaired. A more comprehensive investigation than any undertaken so far seemed required to provide a data base for the development of primary teacher guide materials. It was therefore decided to identify the meanings, ideas and questions which S1 - F4 (7-14 year old) pupils tend to have about floating and sinking. This paper reports on the investigation.

THE INVESTIGATION

There were several parts to the investigation.

1. Interviews

Ten or more children at each level from S1 to F4 were chosen to represent the range of abilities at these levels and were interviewed on each of four schedules. Constraints relating to access to pupils meant that at the F1-4 level the same pupils were not interviewed on the whole four schedules but, in general, interview schedules I and II were undertaken with the same pupils, and interview schedules III and IV were undertaken with another group. Altogether 144 pupils were interviewed.

Briefly, the interview schedules comprised:

(I) a probe of children's meanings for 'floating', using 15 cards with line drawings depicting instances and non-instances of 'floating' (see Appendix 1);

(II) an exploration of children's explanations for why things float or sink, using 10 homogeneous materials, some of which floated (e.g. piece of candle) and some of which sank (e.g. metal paper clip) (see Appendix 2);

(III) an investigation of whether or not children thought length of object or depth of water affect flotation, using materials and objects in water;

(IV) a check of pupils' ability to understand displacement.

An opportunity was taken at the end of each schedule to ask the pupils if they had any questions. The children responded with 99 questions in all.

The interviews were audio-taped and later transcribed.

2. Surveys

A survey schedule was developed as a means of exploring the prevalence of ideas which emerged during the interview phase. Three classes of average or mixed-ability pupils at each level from S2 - F2 (aged 8 - 12 years, 429 in all) were surveyed to find their meanings for 'floating', their views of what would happen to the bottom part of a floating object if the part above water were removed, and their ideas of whether or not the length of an object or the depth of water affect flotation level. The cards and materials used are set out in Appendix 3.

3. 'Lessons' to elicit children's questions and explanations

The researcher visited six classes at the S3-4 level and conducted 'lessons' to elicit children's questions and explanations about floating and sinking. Two further sets of S3-F1 children's questions and explanations were obtained from practising classroom teachers who had elicited them from their pupils during lessons on the topic. A total of 93 questions were recorded. The approaches used by the researcher and teachers to stimulate the children to ask questions are outlined in Appendix 4.

CHILDREN'S MEANING FOR THE TERM 'FLOATING'

There are at least three aspects of floating from a scientific point of view:

> An object or material may be considered to be floating in water if it is at the surface and partly immersed (e.g. a ship), if it is on top of the surface and does not break the surface tension (e.g. a spider) or if it is entirely submerged but freely suspended (e.g. a fish swimming).

Let us now consider children's ideas:

1. When an object was considered to be floating

The interview and survey data reveal that the children generally considered an object to be floating if it was at the surface, slightly immersed in the water, and stationary. For example, with respect to the two cards depicting the apple and person wearing the life jacket, 90 and 104 children respectively of the 104 children interviewed on these items considered them to be floating. Comments included,

> [The apple] "Yes, it's floating. The top of it's up and a little bit is down in the water."
>
> (S1 child)

> [The apple] "Floating. It isn't sinking; it isn't going to the bottom. It stays above the water."
> (F1 student)

> [Person in life jacket] "It's floating because he's on the surface of the water. It's just some parts of the body that are under." (F3 student)

2. When an object was considered to be not floating

Conversely, there were pupils who considered that certain objects were not floating if they were on top of the water, entirely submerged (but freely suspended), or perceived to be moving downwards or horizontally.

(a) Some children considered an object on top of the water to be not floating

If an object was on top of the water it was not necessarily considered to be floating. For example, 33 of the 104 children who looked at the card depicting a spider standing on the surface of the water considered that the spider was not floating. The most common reason given was that it was entirely on top of the water, perhaps being held up by the water's 'skin'. This is illustrated by a S4 child who said,

> "None of him's really under the water, because there's the surface [points] and they can just stand on the water."

and a F1 student who explained that it was not floating because,

> "It's standing on the s... there's a layer of water or something, they don't disturb it. It's like putting a pin on a piece of tissue and getting it to float."

Interestingly, none of the 20 S1-2 children who viewed the card depicting the spider on the water's surface considered that the spider was not floating. It seemed to be a feature of the thinking of some of the older (S3-F4) pupils only. On the other hand, all the 80 children who saw a piece of aluminium foil on top of the water said that it was floating.

(b) Some children considered an entirely submerged, but freely suspended, object to be not floating

An object entirely submerged in the water was likewise considered by a significant number of children to be not floating. For example, 36 of the 114 pupils who were interviewed using the cards said that the person snorkelling under water was not floating. Reasons included,

"He's under the water swimming round."
(S3 child)

"That's just totally submerged under the water."
(F3 student)

One of the survey results provided further evidence of the existence of this view. Of the 419 children who responded to the item which showed a submarine under water, 183 (44%) indicated that they thought it was not floating.

(c) An object perceived to be moving downward was not considered to be floating

When some children perceived that an object was moving downward they did not consider it to be floating. This was clearly illustrated during the interviews using the card depicting a yacht in trouble; 54 of the 104 pupils said that the yacht was not floating. Typical responses were,

"It's getting fuller and it's sinking."
(S2 child)

"It's gonna go down to the bottom." (F4 student)

It should be noted that relatively fewer of the F2-4 pupils 'read' movement into drawings of this kind.

(d) A horizontally moving object was not considered by some children to be floating

For a few children, an object that was moving horizontally was also considered to be not floating. For example, 12 children considered the person swimming at the surface of the water to be not floating because the person was moving along.

"It's using its own energy to push it along."
(S4 child)

"'cause they're propelling themselves." (F3 student)

This is further illustrated by 16 children who considered the speedboat to be not floating, for the same reason.

> "It's going fast, and floating is staying still and just floating around. (S2 child)
>
> "It's not floating because it's moving along pretty fast. Say if it was staying still, it wouldn't sink but it would just stay in one spot... [Would it be floating then?] Yeah, it would be floating then."
> (F2 student)

This idea of something having to be stationary to be considered floating possibly stems from children's swimming instruction where floating tends to be distinguished from swimming.

3. Sometimes an object was considered to be partly floating and partly not floating

As adults, we tend to think that an object is either floating or not. Many children seem quite comfortable employing a third category as well, namely that an object can at the same time be considered both floating and non-floating, or rather than part of the object can be considered floating while another part of it is considered to be not floating. Of the 104 children interviewed, 18 spontaneously used this third type of categorization on 23 occasions. This was especially so with items which depicted the bulk of the particular object below the water's surface. For example, a F4 student said of the beer bottle,

> "Some of it's floating and some isn't. The top part is."

A S3 child commented on the ice berg in a similar way.

> "It's floating and not floating. The top is floating and the bottom's not."

A further illustration was a comment of a S4 child about the person in the life jacket.

> "It's half floating and half sinking. The top half where they're wearing the life jacket's floating but the bottom half are just under the water. [So, would the bottom half be floating?] No, its... the top half's floating but the bottom half isn't."

The same kind of reasoning was evident in the statement of a F3 student about the same item.

> "It's in between... the top half is floating but not the bottom half. Their bottom half is in the water... yeah, I s'pose she is floating because she's got a jacket on her. You know, she's leaning against it and the top half's floating. [So, is the whole person floating?] No, actually I think that the top would be floating, the arms and up here [points to head] but not the body below the waist."

To try to gain some idea of the likely prevalence of this connotation of 'floating', the survey card depicting a bottle partly submerged in water included 'partly floating and partly not floating' as one of the response categories from which the children could choose that response which most closely matched their own thinking. Of the 426 children who responded to this item, 178 (42%) chose this particular category in preference to 'yes', 'no' or 'not sure'.

The tendency of children to classify floaters in this way however, seems largely confined to observing line drawings which depict a cross-sectional view of an object in the water.

During an earlier series of interviews for video filming purposes when three S3-4 pupils were interviewed about materials they could test in water, one of the children did use this third type of classification. But of the 103 pupils who observed materials floating in the bowl of water during the main series of interviews, only one child used this classification. A S4 boy said of the woodblock, pumice and candle that they were half-floating and half-sinking.

CHILDREN'S EXPLANATIONS OF WHY THINGS FLOAT OR SINK

Scientists have several ways of explaining why some things float and other things sink but for our purposes perhaps the most useful explanation is the following:

> An object will float if it has sufficient volume to displace an amount of water equal to its own weight.

Of course, some objects which are light for their size, will settle only a little way into the water before they have pushed aside an amount equal to their own weight. Other objects which are somewhat heavier for their size settle deeper into the water before they have pushed aside an amount equal to their own weight.

It will be seen that most of the children's explanations which follow are not incompatible with the above explanation; it is rather that most fall short of it. They tend to focus on only one aspect and fail to acknowledge other features needed to construct a general explanation that will account for all instances.

1. Children's reasons for why some things float

After the 103 children who were interviewed on the second schedule had experimented with the materials in the water they were asked if there was one reason why some of the things floated. The more common reasons offered are summarized in Table 1.

TABLE 1: Reasons given by S1-F4 pupils to explain why certain things float

REASONS	NO. OF CHILDREN WHO GAVE THE REASON				
	S1-2	S3-4	F1-2	F3-4	Total
1. Because they're light	11	13	5	2	31
2. Don't know	0	1	6	9	16
3. Because they have air in them	1	4	4	5	14
4. Because of the material they're made of	1	4	0	4	9
5. Because they're not compacted or solid	0	0	2	3	5
6. Others	10	8	6	1	25
	23	30	23	14	100

The Table shows that lightness was the most common explanation offered by children for why certain things float. The Table also shows that this explanation was given more often by the S1-4 children and is illustrated by the S4 child who said that things float,

> "'cause they're kind of light"

and the S3 child who explained that certain materials floated,

> "Because they're lighter. [The paper clip is lighter than the pumice though.] Yeah, you think it would float."

Only three of the 31 children who gave 'lightness' as an explanation (one each at the S4, F1 and F2 levels) qualified it by saying that certain things floated because they were light for their size. The rest had an absolute notion of lightness.

A less frequently mentioned reason, but one offered by approximately equal numbers of children at each level from S3-4 to F3-4, was that certain things float because they have air in them. This is illustrated by the S3 child who said,

> "The air passing inside them would keep them afloat."

This was perceived to be the case especially with objects which contained holes such as the piece of pumice. This is illustrated by a F1 student who predicted that the pumice would sink but then observed that it floated.

> "It floats! I think it's 'cause it's got holes in there and so the air can get in."

It is further illustrated by a F4 student who explained that the pumice floated because,

> "It's got an air mass inside to keep it afloat."

That certain things float because they have air in was also offered by children in all six S3-4 classes who were invited to write possible answers to the question 'Why do some things float and some things sink?' For example, one group of S3 children wrote,

> "Some things have air in them like rubber balls, rings and many more things, and that is why they float."

The F1-4 students were more aware that they did not know the reason. Many pupils hesitated then said that they did not know, as the comments of the following students show. They were asked 'Is there one reason why these materials floated?'

> ".... um... not all of them are light... I don't really know." (F4 student)

> .... ah... there probably is one reason why they floated... but I don't know what it is." (F2 student)

The point about some pupils being aware that they did not know why certain things floated is confirmed by the fact that by the end of the interviews about materials the S3-F4 pupils had asked 36 questions seeking reasons for why various things floated, for example,

> "I've always wanted to know why wood floats 'cause it doesn't seem to have any kind of big holes in it or anything." (S4 child)

> "Why did the pumice float?" (F3 student)

The point is further supported by children in eight S3-F1 classes asking 65 questions seeking explanations of why certain things float, for example,

> "Why do most plastics float?" (S3 child)

> "Why does oil float on the top of the surface; it seems like a liquid itself?" (S4 child)

Another less common reason why certain things float given by some children during the interviews was that it depended on the <u>type of material</u> of which they were made. Sometimes this was expressed in a general way, for example,

> "I suppose it's the kind of material used to make them up." (F4 student)

and at other things a more specific feature of the material was referred to, such as it being <u>not solid</u> or <u>not compacted</u>, for example,

> "That [pumice] feels heavy but it isn't really; it's not compacted." (F3 student)

or having <u>water resistant qualities</u>, for example,

"Wax is water resistant I think and it [the candle] wouldn't go, all go under water. It's not letting the water absorb into it." (F2 student)

Another reason offered less often was that certain objects floated because they were held up by the part above the water line. For example, in response to being asked what would happen to the iceberg if the top could somehow be cut off, a F2 student replied,

"It will sink because the top bit is obviously holding it up."

and a S4 pupil said,

"It'll sink, the bottom bit. [Why do you think that?] It's the top bit that's helping it float."

During 'lessons' when children's questions and answers about floating and sinking were elicited, a few children also suggested that some things float because of gravity, water pressure, their origin (man-made products can float but nature-made ones cannot, except for wood), their shape (they have edges around them) or the fact that they have a motor (big metal things float because there is a motor in them).

2. Reasons why some things sink

The more common reasons given by children during the interviews to explain why certain things sink are shown in Table 2.

TABLE 1: Reasons given by S1-F4 pupils to explain why certain things sink

REASONS	NO. OF TIMES REASON GIVEN				
	S1-2	S3-4	F1-2	F3-4	Total
1. Because they're heavy	12	16	10	8	46
2. They are solid, compact, dense	0	1	4	6	11
3. They have no air in them	1	3	3	4	11
4. It is the material they're made of	1	5	1	2	9
5. Don't know	1	0	5	1	7
6. Because they absorb water	1	2	2	1	5
7. Others	7	7	6	5	26
	23	34	31	27	115

It is evident from Table 2 that by far the most common reason given by the children for why certain materials sink is that they are considered to be heavy. This is illustrated by a S2 child who, when asked why he thought some of the materials sank, said,

"They are all a bit heavy."

A F3 student replied in a similar manner, but was aware of an anomally in his reasoning.

> "I think most of these sink because they're quite heavy, and chalk, I wouldn't know."

One S4 child, however, could account for the small piece of chalk sinking (after she predicted that it would float) in terms of its heaviness. She said,

> "It definitely sunk, 'cause it's quite heavy and it managed to break the water's surface. [I thought you said it was light before.] It was; it was light to us but it was heavy to the water."

The same three pupils who said that certain things floated because they were light for their size also qualified their answer of why certain things sank. They explained that it was because they were heavy for their size, an explanation which is consistent with the scientific view.

The idea that things sank if they were solid, compact or dense was expressed by a few of the older students. For example, a F1 student said that the piece of chalk sank because,

> "It's heavy... not heavy, but it's solid."

Another F1 student said the plasticine sank because,

> "It's compacted. [What do you mean by that?] It's in a tight ball so it would hardly float."

A F4 student gave a similar reason.

> "[The plasticine ball] "It was more denser and heavier. [How do you mean, dense?] Um... the properties are sort of more pushed in tighter and makes it heavier."

More generally, a F2 student said that some of the materials sank because,

> "They're kind of impacted in, and all the tiny bits are squashed together."

and a F3 student said they sank,

> "Because of their bulk, not bulk, they're tightly packed, the particles are all tightly packed... That one there [points to aluminium block] is a whole lot of solid particles and they're all tightly packed."

Some children also thought that certain things sank because they had no air in them. For example, a S4 pupil said that the plasticine sank because,

> "It's all in a round ball and no air pockets in it."

and a S3 child concluded that the piece of chalk sank,

> "Because it must have no holes in it to gather up the air like pumice does."

Other reasons given by a few students for why certain things sank included:

(a) the type of material of which they were made. For example, a S3 child said the paper clip sank because,

> "It is made of um, aluminium I think, tinny stuff. All stuff that's got like metal or steel will always sink."

(b) they absorb water, for example, a S1 child expressed the view that the piece of chalk sank because,

> "It's got too full of water. That makes it sink, kind of like a sponge."

(c) the student didn't know the reason, for example, a F2 student said of the piece of chalk,

> "I thought it would stay up seeing it is so small. [Why did it sink?] I'm not sure really, um, I don't really know."

Questions asked by S3-F4 students during the interviews (27 questions) and by S3-F1 students in the class 'lessons' (32 questions) also suggest that a number of pupils realised that they did not know why certain materials sink. For example, during an interview a F2 student asked,

"I didn't know the plastic would sink. Why did it sink?"

and during a class 'lesson' a S3 pupil asked,

"Why do most metals sink?"

In the class situations some children suggested a few more reasons for why certain things sink. These included the presence of holes. For example, a S3 group wrote,

> We think things with holes in them will sink because of the weight coming down and the water coming up through the hole."

and the researcher observed a small group of S4 boys piercing (and later enlarging) a hole in a piece of candle to see if it would sink when the water came up through the hole. This same idea of holes causing things to sink arose in one interview. A S4 girl said that the wood block floated because,

> "It's quite light and the water isn't getting through... getting in... isn't going through. [What if I put some holes in it?] Probably sink."

Being filled with water was another reason given, for example,

> "When a fishing boat is full of water it will sink. (S4 group)

3. Some features of the children's explanations

Several features of the children's explanations are of interest. These relate to their understanding of the principle of flotation, their giving of multiple reasons, the consistency of explanation and the form their explanations took.

(a) Understanding of the principle of flotation

Only one of the 103 students interviewed (a F4 boy) could be said to have some understanding of the principle of flotation with respect to materials. He explained that some of the materials floated because,

> "Their density is less than one gram per cubic centimetre. If you got a cubic centimetre of all those [floaters] they'd be less than a gram."

He further explained that,

> "If you got a cubic centimetre [of each of the sinkers] those'd be more than a gram."

However, he said that he did not know why 'one' should be the middle point, apart from the fact that they had 'done' it in science a few months previously. The fact that 102 of the 103 pupils interviewed did not have an understanding of the principle of flotation is consistent with the findings of the studies cited at the beginning of the paper.

(b) The use of multiple reasons

At the end of the interviews about materials each child was asked if he or she could think of <u>one</u> reason why the floaters floated, or <u>one</u> reason why the sinkers sank. The number of reasons given by the pupils for each condition are set out in Table 3.

<u>TABLE 3:</u> Number of pupils and number of reasons given as to why certain materials floated or sank

No. OF REASONS	No. OF CHILDREN									
	S1-2		S3-4		F1-2		F3-4		Total	
	float	sank	float	sank	float	sank	float	sank	float	sank
Single reason	4	7	12	17	8	9	5	8	29	41
Multiple reasons	13	10	19	14	12	12	6	9	50	45
No reason	3	3	3	3	8	7	10	4	24	17
	20	20	34	34	28	28	21	21	103	103

The main feature of Table 3 is that approximately half the pupils in each case gave more than one reason to explain why certain materials either floated or sank. The impression gained during the interviews was that these pupils could not really conceive that a single explanation was possible. On the other hand, the F3-4 students seemed more aware that a single explanation was possible, although they didn't necessarily know what it was.

(c) Consistency of explanation

One hundred of the 103 children interviewed with respect to materials were entirely consistent in their explanations of why some floated and some sank. Typical was the series of explanations of a S2 child who said that each of the floating materials was light or had air in it, while each of the materials which sank was heavy or let the water in.

(d) Explanations were in the form of laws

Von Pfuhl Rodrigues (1980) found that the 15 children (aged 7-13 years) that she studied all gave explanations in the form of laws, although these changed with increasing age from very specific to more general.

In the present study the children, for the most part, also gave explanations in the form of physical laws. There was really only one instance of a child giving an explanation that was of a type other than a law. A S3 pupil, when asked if there was one reason why some of the materials floated, said,

> "I don't know, just, they're most probably just used to it. [And the sinkers?] They aren't used to it."

The fact that many of the younger children reverted to giving explanations for individual materials when asked for one reason why some materials floated and some sank, whereas none of the F3-4 students did this, suggests that there was a trend towards offering more general rules with increasing age. However, if the actual reasons given by all the pupils for individual materials are considered (rather than their

attempted 'general rule') then the overall impression gained is that there was very little difference in reasoning with age. For example, there were pupils at the S2, S4, F2 and F4 levels who gave similar reasons for why the chalk sank;

> "The water got in and it got all wet and it just sank to the bottom. The water made it heavy." (S2 child)
>
> "Maybe 'cause the chalk was wet and it brings it, the chalk down." (S4 child)
>
> "The water might've made it heavier or something; it sank. [How do you mean?] Well, when it hit the water it probably filled up with it and got heavier." (F2 student)
>
> "Probably water logged. [Would this dry bit float?] That would, it's quite dry but it'd get wet very quickly and probably sink too." (F4 student)

The general lack of difference in reasoning among children of different ages is further illustrated by the similar explanations given by S1, S3, F1 and F3 pupils of why the pumice floated.

> "It's got lots of holes, lets air inside it and that keeps it from going down." (S1 child)
>
> "Because pumice is, even though it feels heavy it's got holes through it and the holes sucks in air that keeps it afloat." (S3 child)
>
> "Probably got pockets of air inside it." (F1 student)
>
> "Probably 'cause it's got those little holes in it which carries air and all that in." (F3 student)

IDEAS RELATING TO FLOATING MATERIAL IF THE OBJECT WAS CHANGED OR THE DEPTH AND DISPLACEMENT OF WATER ALTERED

1. Children's views of what would happen to floating material if the part above water were cut off

Children varied in their ideas about what would happen to the bottom part of a floating material if the part above water were cut off. During the interviews using the cards, many of the children were asked what they thought would happen to the bottom part of the iceberg if the top part were cut off. During later interviews, children were asked what they thought would happen to the bottom part of the pumice (which they observed floating) if the part above water were cut off.

Just over 40% of children in each case thought that the bottom part of the material would rise, as indeed it would. For example,

> "The bottom [of the iceberg] would come up a wee bit more. It'd keep on coming up if you kept on cutting the top off." (S3 child)
>
> [The iceberg] "Oh, probably rise up a little. It'll probably take some weight off it." (F4 student)
>
> [The pumice] "It will bob up a bit higher because there's not so much weight on top." (S2 child)
>
> [The pumice] "It'd float a bit, a little higher up 'cause it's lighter than what it was." (F2 student)

Thirty percent of the children thought that the bottom part would sink if the part above water were cut off. Reasons included,

> [Iceberg] "Because ice is quite heavy and it will drop like a stone." (F1 student)
>
> [Iceberg] "I think it will sink 'cause the weight of it has got to be balanced by the top bit." (F3 student)
>
> [Pumice] "There's nothing to hold it up." (S3 child)

[Pumice] "If you cut the top off, all the air goes out from underneath and it fills up with water." (F1 student)

[Pumice] "The bottom would sink because all the water would get over the top of it." (F3 student)

About 8% of the children considered that the bottom part would stay at the same level, for example,

[Iceberg] "I think it would just stay where it was [points with finger]." (S4 child)

[Pumice] "The bottom bit will stay under where it is. Pumice is light and it won't sink." (S1 child)

The idea of 10% of the children that the bottom part of the pumice would roll over and float was unexpected. The children's comments included,

"It would flip over because the round bit always stays at the top." (S2 child)

"It would turn over because the top would be lighter than the bottom." (F1 student)

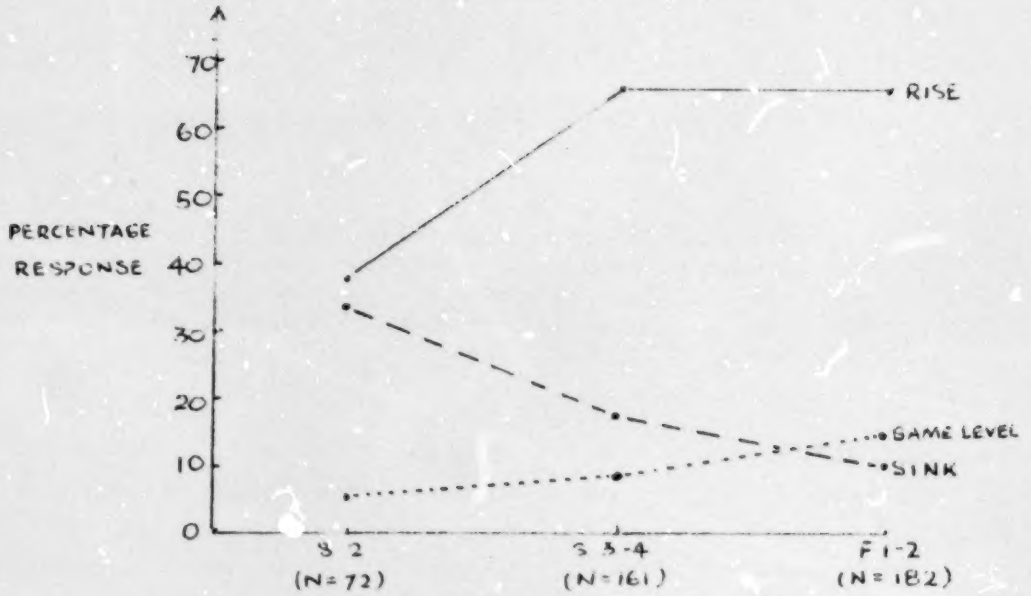
The prevalence of these ideas among children at the S2-F2 level was investigated by survey using a picture of an iceberg. The results are shown in Figure 1.

Figure 1 shows that a majority of children at each level considered that the bottom part of the iceberg would rise if the top were cut off. It also shows that the percentage of children who thought that it would sink declined from 33% at the S2 level to 10% at the F1-2 level.

2. Views of whether the length of material affects the level at which it floats

Two interview items sought to probe children's ideas about the level at which they thought a long piece of material would float compared with a shorter piece of the same material which they saw floating. Different lengths of candle and wood were used, in that order.

FIGURE 1: S2-F2 children's views of the behaviour of the bottom part of an iceberg if the top were cut off



The children made a variety of predictions about the outcome of altering the length of the candle. Some 20% of pupils interviewed predicted that the longer candle would float at the same level as the shorter one, which it does. For example,

> [The longer candle] "It'll float about the same 'cause they're the same size except that one's longer, but they're the same width." (S4 child)

> "It would float about the same level. It's like a log. It's just the same as that wee candle, just like if you had cut it up. It's just like that wee candle and it's, even though it's put together it would still float because it's light." (F1 student)

Over 30% of the children considered that the longer candle would float at a lower level, for example,

> [The candle] "It will float a bit further down because it's bigger and it's probably a bit heavier than the smaller one." (S4 child)

> [The candle] "It will float a little bit lower because it's heavier." (F2 student)

About 25% of the children thought that the longer candle would sink. Typical predictions were,

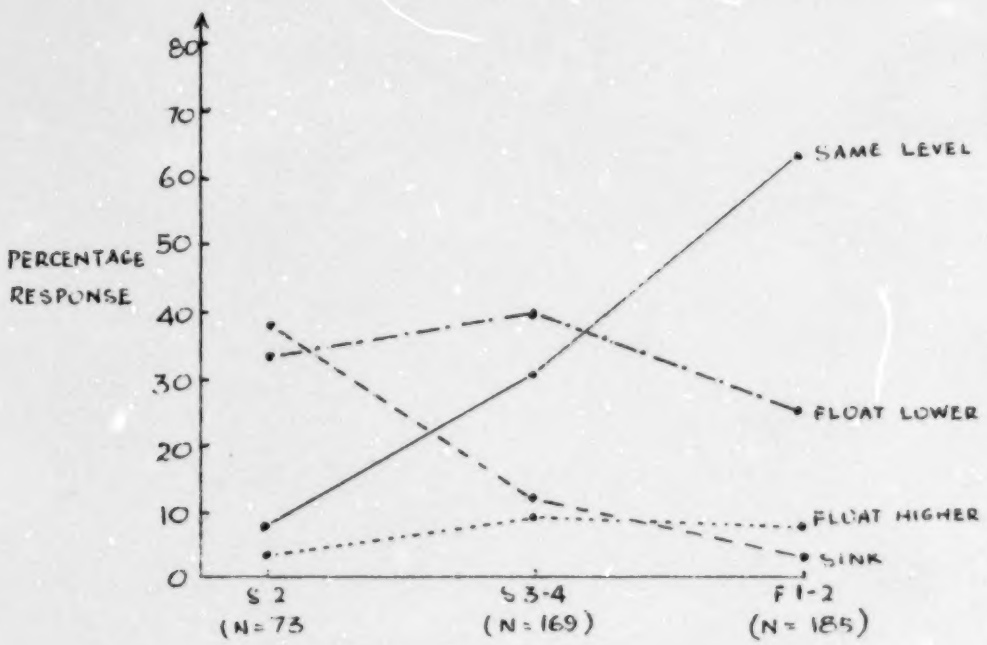
> "[The candle] "It'll sink. It's longer and it's more heavier." (S3 child)
>
> [The candle] "It'll sink because it's heavier than the lighter candle." (F3 student)

One or two pupils even considered that the longer candle would float at a higher level, for example,

> "[The candle] "It will float, higher up I think because of the water pressure underneath it... is lifting it out a bit more than the little piece." (F2 student)

To investigate the prevalence of the various ideas that children hold regarding length of material and flotation level, pupils at the S2-F2 level were surveyed with the same materials (candles) and approach used in the interviews. The survey results are shown in Figure 2.

FIGURE 2: S2-F2 pupils predictions about the flotation level of a full length candle compared with a short piece of candle



The survey clearly shows that as the children got older, an increasing percentage considered the longer candle would float at the same level as the smaller candle (less than 10% at the S2 level to approximately 65% at the F1-2 level) and that a decreasing percentage considered the longer candle would sink (approximately 40% at the S2 level to less than 5% at the F1-2 level), or float lower.

After the children who were interviewed had made their predictions about the flotation level of the longer piece of candle, compared with the shorter piece, they were given an opportunity to test their predictions. They found, of course, that the longer piece floated at the same level as the shorter piece. Would this knowledge influence their predictions about the flotation level of a longer piece, compared with a shorter piece, of another material such as wood? This was investigated and the results of comparing the children's predictions about longer pieces of candle and wood are shown in Table 4.

TABLE 4: Comparison of children's predictions about the flotation level of longer pieces of candle and wood (compared with shorter pieces of the same material)

		No. OF STUDENTS			
		S3-4	F1-2	F3-4	TOTAL
PREDICTIONS THAT CHANGED	Changed to same level	10	7	7	24
	Changed from same level	2	1	3	6
	Changed from sink to float lower	2	4	3	9
	Changed in other ways	3	2	1	6
	Total	17	14	14	45
PREDICTIONS THAT DID NOT CHANGE	Predicted same both times	1	1	3	5
	Predicted sink both times	2	0	1	3
	Predicted lower level both times	0	5	2	7
	Total	3	6	6	15

It might be expected that those children who predicted that the longer piece of candle would float at the same level as the shorter piece would maintain this prediction for the longer piece of wood, and that those who had made other predictions would change to this prediction after their experience of testing the longer piece of candle. The results, which show little difference between age levels, indicate that this expectation would be over-optimistic. Only five of the 11 children who predicted that the longer piece of candle would float at the same level as the shorter piece actually maintained this prediction for the longer piece of wood, and slightly less than half the number of children (24 out of 49) who had predicted otherwise for the longer piece of candle changed their prediction for the longer piece of wood in the way expected. Thirty-one of the 60 children did not make predictions in the direction that might be anticipated. They did not, or were not willing to, generalise from the single experience with the candle - a strategy not to be discouraged in the field of science - and the implication is that some children may require several such experiences to realise that the length of a material does not affect the level at which it floats.

3. Views about whether the depth of water affects the level at which an object floats

The depth of water which may be thought to affect the flotation of an object can be underneath the object or on top of it. To investigate the first case, the children who were interviewed were shown a plastic boat floating in a bowl of water. They noted which mark on the side of the boat the water level was at and were asked to predict which mark it would be at if the boat were in a deep lake.

More than half the pupils interviewed predicted that the boat would float at the same level, which is the view that scientists would take. Typical comments were,

> "It doesn't matter how deep the water is. It's [depends on] how heavy the boat is." (F1 student)

> "The water's still, I mean the boat is still the same weight. I mean it's not going to be put down any further; it doesn't matter how deep the water is." (F4 student)

Twenty-five percent of the children interviewed predicted that the boat would float at a lower level.

Reasons given included,

> "Because the water is deeper and sort of sucks it down."
> (S3 child)

> "It might sort of go down more. It's much deeper and that, much more water." (F3 student)

About 16% of the children interviewed predicted that it would float at a higher level. Examples of their explanations are,

> "There is more weight from underneath to hold it up."
> (S2 child)

> "Because it's a greater volume of water and it's got more pressure in it to lift it, to hold it up."
> (F2 student)

The prevalence of these ideas among S2-F2 children was investigated bu survey using a picture depicting a launch setting out from a jetty at the edge of a lake into the deeper water. The children's predictions about the level of flotation of the launch in deeper water compared with the level of flotation in shallower water are shown in Figure 3.

FIGURE 3: S2-F2 children's predictions about the level of flotation of a launch in deeper water.

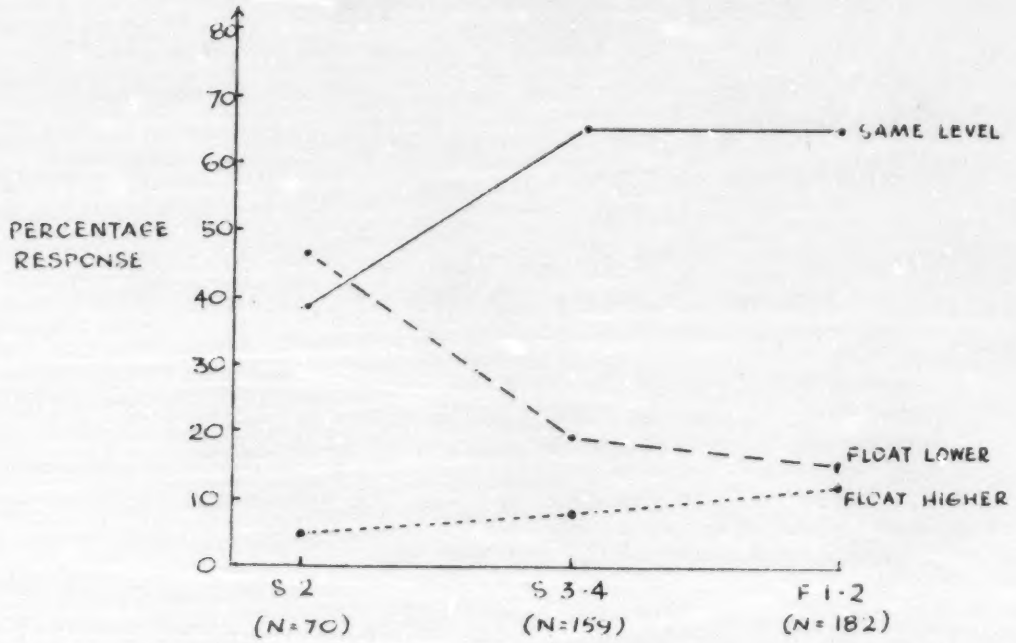


Figure 3 shows that by the S3-4 level the majority of children considered that the launch would float at the same level. However, even at the F1-2 level there were some children who predicted that it would float at a different level.

To investigate the possibility that some children might think the level of water on top of an object would affect its flotation, the chilren interviewed were shown a block of wood floating and asked to predict what would happen to it if it were placed on the bottom of the ocean. The children's predictions are shown in Table 5.

TABLE 5: Number of children and their predictions of the behaviour of a wood block placed on the ocean floor

PREDICTION	No. OF CHILDREN				
	S1-2	S3-4	F1-2	F3-4	Total
It will rise	15	16	15	13	59
Stay on bottom	5	4	5	6	20
Not sure	0	0	0	1	1
	20	20	20	20	80

The Table shows that the majority of chilren held the scientific view that the wood block would rise. Typical comments were,

> "It will come back up. It'd be um, like the candle, when I pushed it down and it came back up; it'd be like that, come back up." (S3 child)

> "It'll rise 'cause the current will make it float up." (S4 child)

> "It will float back up again... the wood is lighter than the water. [Than all the water in that part of the ocean?] Well, see if you take the volume of water which is... take as much water as the block would take up, then you'd probably find that the block would be lighter. [Some people think that the water pressure would hold it down.] It could. I'd have to look it up in the books to find that." (F4 student)

However, one quarter of the children predicted that the wood block would stay on the bottom. Their reasons included,

> "It's really deep and it sucks it down like the plasticine and the ship." (S3 child)
>
> "It will stay on the bottom... [There would be] too much pressure, on top of it." [F3 student)
>
> "It'd jut get sort of crushed because of the pressure from the water... so deep. [It wouldn't be a block any more?] No, it'd just be a sort of a blob." [F4 student)

4. Some children's ideas about shape and floating

One aspect of children's ideas about the effect of a shape on floating was investigated as a side issue. Children at the S3-F4 level were shown a 3cm solid cube of plasticine which sank when they put it into the water. Next they were shown a plasticine cube of similar dimensions, but with the middle hollowed out, and asked to predict what would happen to it if it were placed in the water.

The children were not unanimous in their predictions. In fact this is not surprising as the hollowed-out plasticine cube could have been made to float or sink. As it was, it only just floated. The children's reasons for their predictions are therefore of greater importance than their actual predictions.

Almost half of the children predicted that it would float. Their reasons included,

> "Water can't go up the sides and get in." (S3 child)
>
> "Because it's hollowed out and not so heavy." (F2 student)
>
> "It'd sink part-way down and that hole gets filled up with air and it'll float." (F3 student)

About 40% predicted that it would sink. Typical explanations were,

"It's a square and it's hard and heavy."
(S3 child)

"It's just the same as the other block [solid cube of plasticine]. The substance is no different. It should still sink." (F4 student)

Ten percent said they didn't know or they were not sure, for example,

"I don't really know. It might float because it's not very, it's not so heavy, but it might sink 'cause there's not enough, it's too heavy for the water.
(F3 student)

A summary of the children's predictions is shown in Table 6.

TABLE 6: Children's predictions when asked whether a hollow plasticine box would float

PREDICTION	No. OF CHILDREN			
	S3-4	F1-2	F3-4	Total
It will float	10	9	10	29
It will sink	9	10	6	25
Not sure or don't know	1	1	4	6
	20	20	20	60

When the children were next confronted with a variation of this activity using an amount of plasticine equivalent to the solid 3cm cube, but fashioned into a 'canoe' shape, 56 of the 60 children correctly predicted that it would float. The other four, all at the F3-4 level, were not sure.

5. Views about the amount of water displaced by objects made from the same amount of material

Two items were included in the last interview schedule to explore the children's understanding of displacement. The materials used in the first of these comprised a ball of plasticine and a hollow box made from an equivalent amount of plasticine. The children observed how much water

the ball displaced as it was lowered under the water. They were then asked to predict how much water the submerged box would 'push out' compared with the ball. It was made quite clear that the box would be submerged with the opening to the side so that only the plasticine could displace the water. The children's predictions are shown in Table 7.

TABLE 7: Children's predictions about amount of water displaced by a hollow box compared with that displaced by a ball made from an equivalent amount of plasticine

PREDICTION	No. OF CHILDREN				
Sunken box will push out...	S1-2	S3-4	F1-2	F3-4	Total
The same amount of water	11	9	1	5	26
Less water	9	6	18	13	46
More water	0	5	1	1	7
Don't know	0	0	0	1	1
	20	20	20	20	80

Both objects would displace the same amount of water when submerged. Approximately one-third of the children, the majority of these being at the S1-4 level, predicted that this would be the case. Typical comments were,

"Because they're the same amount, just different shapes."
(S1 child)

"Because they're made of the same amount of stuff."
(S4 child)

"Exactly the same, because it's the same volume."
(F4 student)

More than half of the children predicted that the hollow box would displace less water. Their reasons included,

"Because it will take in water in the hollow as it goes down."
(S2 child)

"It has that room [hollow inside] to put the water into."
(F2 student)

"It'll fill with water; it'll hold some of the water that would overflow with the ball." (F4 student)

It may be that some of the children who predicted that the hollow plasticine box would displace less water than the ball of plasticine misinterpreted the question.

A few of the chidlren had the idea that the hollow box would displace more water. They seem to have been influenced by the size of the box, for example,

"It's a little bit bigger." (S3 child)

"Although it's the same weight, there's more area [in the box] of plasticine, making more water spill over." (F3 student)

The second item also made use of the hollow plasticine box. It was used to investigate the children's predictions of the amount of water the hollow box would displace when floating, compared with when it was submerged, and to explore their explanations for their observation that the box displaced more water when floating than when submerged.

The children's predictions about the amount of water the hollow box would displace when floating, compared with when it was submerged, are shown in Table 8.

TABLE 8: Children's predictions about the amount of water a floating plasticine box would displace compared with the amount displaced when submerged

PREDICTION	No. OF CHILDREN				
	S1-2	S3-4	F1-2	F3-4	Total
More water	2	3	3	3	11
Less water	12	12	11	14	49
Same amount of water	6	5	5	3	19
No water	0	0	1	0	1
	20	20	20	20	80

Approximately 14% of the pupils predicted that the floating plasticine box would push out more water than when it was submerged, which it does. Typical reasons offered were,

> [Floating plasticine box] "It's got a bigger shape and no water can go in there [in the hollow]."
> (F2 student)

> "It's definitely going to be more... yeah... it's taking up more space." (F4 student)

More than 60% of the children interviewed predicted that less water would be pushed out. Reasons offered were very similar and related to the floating box being not as far in the water as the submerged box, for example,

> "Because when you're putting that [floating box] in, the water'll come out but you won't be putting the whole thing in, and so that extra bit more [water] won't come out." (S4 child)

> "A bit more, oh no, hang on... I think it'll push out just a little bit less 'cause if it's going to be floating, it won't be pushing out the same amount; there'll still be some more [box] above the surface."
> (F4 student)

Almost 25% of the pupils predicted that the same amount of water would be displaced. Reasons included,

> "It's the same plasticine, exactly." (S1 child)

> "I think it'll be about the same 'cause it's still the same weight even if you push it down further enough."
> (S3 child)

> "It's the same plasticine model." (F3 student)

One child even thought that the floating plasticine box wouldn't push out any water

> "Because when you put it up that way [vertically] it kind of floats up; it doesn't sink under."
> (F1 student)

After making their predictions, the pupils observed that the floating plasticine box pushed out more water than when it was submerged. The

scientific explanation for this is that the box was actually occupying a greater volume (space) in the water when floating than when submerged. The children's main reasons for why the floating box displaced more water are shown in Table 9.

TABLE 9: Children's reasons why the floating plasticine box displaced more water than the same box submerged

REASON	No. OF CHILDREN				
	S1-2	S3-4	F1-2	F3-4	Total
Water couldn't get inside	0	3	7	4	14
It was taller	7	1	5	1	14
Don't know	9	13	4	11	37
Other reasons	4	3	4	4	15
	20	20	20	20	80

Some of the children seemed to have an intuitive idea of the scientist's view as expressed in their comment that the water couldn't get inside, for example,

> "I think I know, 'cause the water, when it got into it last time, well the water could get in there and so that means that it didn't come out [of the container] but this time when no water could get in it [inside the hollow box] it all had to come out 'cause there was no room [in the container]. (F1 student)

Those children whose explanation referred to the tallness of the box when floating also seemed to be on the way to understanding but their notion was somewhat vague compared with that of the previous group, for example,

> "It might have something to do because it's taller and it's got more to push in." (F2 student)

> "It's taller, that's all I can think of." (F3 student)

Almost half the children were very puzzled by their observation. It was quite unexpected and they couldn't explain it, for example,

"I don't know why... bit confusing. It's just the same weight but... hmm, how'd that happen? No, I don't know."
(S4 child)

When, at the end of the interview, the pupils were asked if they had ary questions, some returned to the floating plasticine box and made further comments or asked questions, for example,

"Why did that one [floating box] push out more [water] when it was floating, but when it was on its side it only pushed out a little bit?" (F1 student)

"Why did that [floating box] push out more water than the other one [submerged box] did?" (F3 student)

"I was a bit confused about that, how when it [plasticine box] was floating.... while it was on its side I thought myself it would push out the same [amount of water] both ways, but obviously it didn't."
(F4 student)

"I'm still not quite sure about the floating plasticine [box] because I reckon this didn't go fully under the water, yet this when it was on its side did, and it [floating box] still pushed out more water."
(F4 student)

CHILDREN'S QUESTIONS ABOUT FLOATING AND SINKING

Of the 93 questions about floating and sinking asked in eight classes by children at the S3-F1 level, over 50% related to materials or objects, for example,

"Why does sand sink?"

"Why do pins and needles float?"

"Why do most metals sink?"

"Why do most plastics float?"

How do icebergs float?"

Why does oil float on top of the surface; it seems like a liquid itself?"

Although there is no simple answer to questions of this type it may nevertheless be possible to lead primary age children, through

investigations, towards an understanding that things which are light for their size float, while things that are heavy for their size sink. Indeed the question of size and flotation is something that puzzled a number of children who asked questions such as,

> "Why do big ships float and why do little things like paper clips sink?"

Sometimes the puzzlement was about weight rather than size, for example,

> "Why don't ferries sink because the cars and trucks are heavy?"
>
> "Why does wood float because it feels really heavy on land?"

A further 10% or so of the questions asked were in a more general form, for example,

> "Why do little things sometimes sink and big things sometimes float?"
>
> "Why do light things sink and some heavy things float?"
>
> "Why do some things float and some things sink?"

The questions about materials and objects were really specific instances of these more general questions. So too were the questions asked about people and other animals which comprised approximately 20% and 10% respectively of the total. Examples of these questions are,

> "Why do some people float and some people sink?"
>
> "Why do babies float and big people sink?"
>
> "When people fall in water how come their head is always facing down?"
>
> "Why do you sink when you dive in and why do you kind of float up when you are holding your breath?"
>
> "How come if we're in our undies and T-shirt we sink, but we don't if we're in togs?"
>
> "How come dead things usually float?"
>
> "Why don't tiny insects sink?"

Again, there are no simple answers to questions of this nature but some could certainly be investigated further. For instance, children could investigate the effects of taking different sized breaths while in the water. The question about undies and T-shirt could perhaps be broadened to investigate the effects of wearing different types of clothing in water including jeans, gumboots and buoyancy aids such as life-jackets.

As asked by the children, only a few of their questions would be directly investigable, for example,

"Do all stones sink, even if they're little?"

"Do heavy things float?"

"If you put water in a balloon, does it sink?"

"Is it because there is salt in sea water that ships float?"

"What kind of things make you float?"

"Do fish sink when they're dead?"

"How come paper boats don't sink straight away?"

As they stand, a few more questions could probably be investigated by reference to books or knowledgeable people, for example,

"Can things float in the water forever?"

"How come submarines sink but battleships float, and yet they're made of the same material?"

"How can a dry dock float?"

A very few of the questions asked were rather unusual in that they either went beyond the topic or they were questions which a teacher would not normally expect, for example,

"How come if you blow a bubble through a square hole it comes out round?"

"If space was filled with water, would the world sink?"

Such questions illustrate the range of questions that may be asked in a classroom in response to stimuli provided by the teacher.

Almost all of the questions reflected knowledge-gaps or puzzlement on the part of the children. A few also reflected restricted views held by some children, for example,

"Why do light things float?"

"Why don't eggs float?"

"Why do stones sink?"

"How come wood does not sink?"

"When you put water in the petrol tank, why does it float?"

"Why do leaves float?"

The questions asked by the children indicate that they drew upon both the stimuli provided by the teachers and their own experiences to formulate them. They were also prepared to use their prior experiences to construct possible answers to a number of their questions and these provide additional insights ito their thinking. For example, in response to their question, "Why don't you float in the bath?" groups of children in one class wrote answers which included,

"It's too shallow."

"It isn't big enough."

"It all depends on what size bath you've got."

"Because it's warm, not cold."

"You would if you're dead."

The insights into children's thinking provided by their questions and explanations could be of considerable value to a teacher offering guidance to children during the course of activities on floating and sinking. For example, they may enable the teacher to challenge some of the children's ideas by directing their observation to aspects being overlooked or by inviting them to consider alternative explanations.

SUMMARY AND IMPLICATIONS

The interviews revealed that different children attached different meanings to the term 'floating' and that this varied with context (such as observing real objects in water as opposed to viewing line drawings). The indications are that the pupils are still at the formative level with respect to this idea and that there are likely to be children in most classrooms whose meaning for 'floating' differs from that of scientists. If this is not recognised then teaching could lead to confusion for some pupils.

The children had a range of views about why some things floated while others sank. In a significant number of cases, the younger children (7-10 years) did not realise that there could be a single explanation. Their response was to begin giving explanations for individual materials. The explanations offered, whether multiple or single, could be described as partial explanations. They focussed on specific aspects such as lightness or heaviness and failed to take into account other aspects (such as size) needed to formulate a general rule that would explain all cases. Only one of the students seemed to have an understanding of flotation which approximated that of scientists. Others, especially at the F1-4 level, realised that they did not really know why things floated or sank, but they appeared interested to know.

A number of children had the idea that the length of floating material, or the depth of water underneath or on top of an object, affected flotation level. Some further believed that floating material would sink if the part above water were cut off, or if it had vertical holes put through it. After an initial experience with reshaped non-floating material, almost all the children realised that non-floating material could be shaped to float.

Many of the children were quite puzzled by their observations of the displacement activities. Nevertheless, almost without exception, they said that they enjoyed working with and thinking about the various materials. Their ideas and positive feelings toward 'floating and sinking' suggest that it is a topic with potential; there are many simple ideas about flotation that can be developed at the primary level which are useful in their own right, as well as being essential to the grasping of the scientist's explanation later on.

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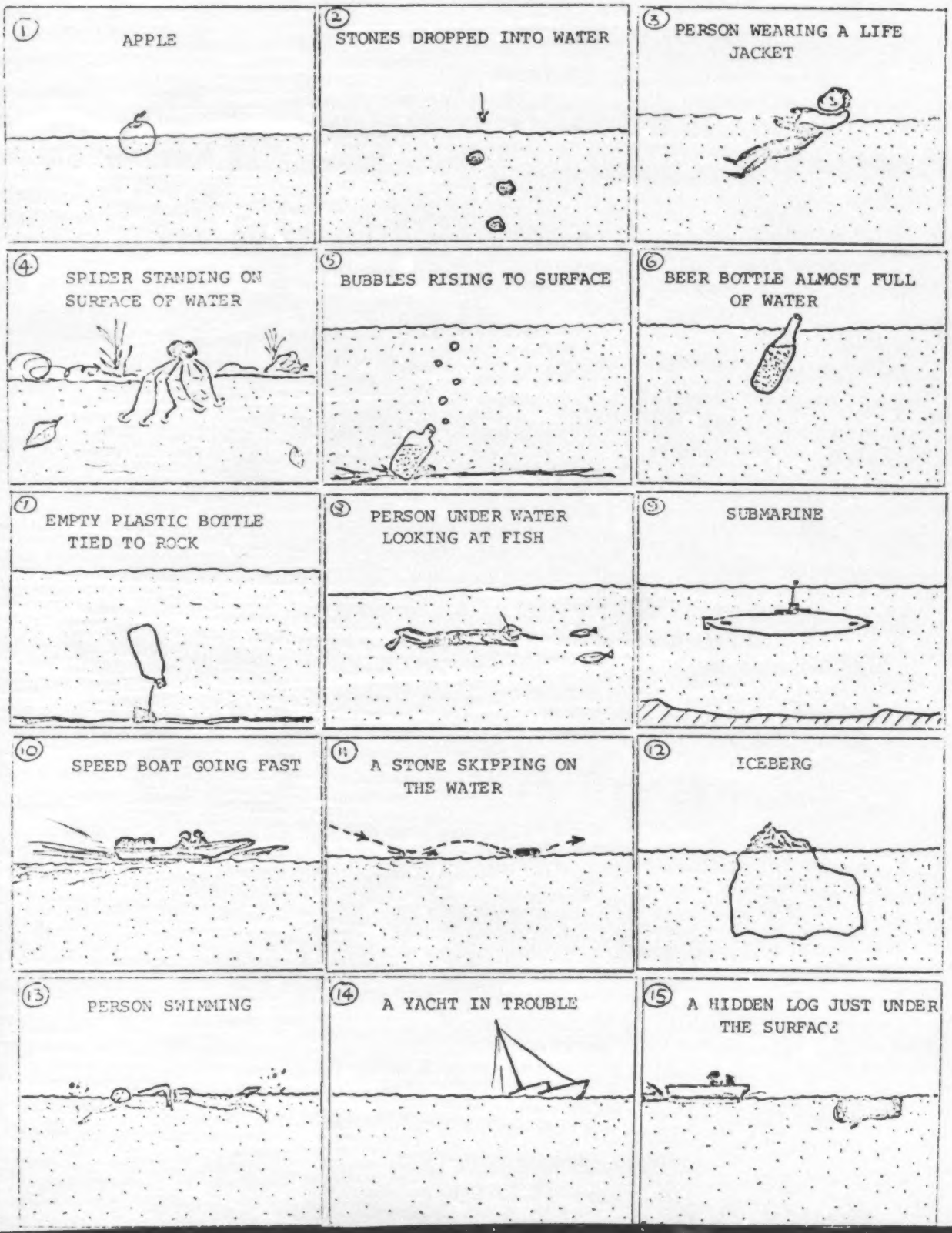
APPENDIX 1: Instances and non-instances of 'floating'

Approach used: "In the way you think about 'floating', would you say the _____ is floating, or not?"

"Why do you think that?"

Investigation of anomalies via further questioning



APPENDIX 2: Materials used in second interview schedule

1. Small, rectangular wood block, approximately 60mm x 40mm x 20mm
2. Metal paper clip
3. School rubber (eraser)
4. Oval piece of pumice, approximately 70mm x 50mm
5. Short length of candle, approximately 65mm
6. Small block of aluminium, approximately 25mm x 25mm x 10mm
7. Flat piece of thin polystyrene, approximately 75mm x 55mm
8. Flat piece of thin fibreglass/perspex, approximately 115mm x 75mm
9. Small piece of white chalk resembling pebble, appoximately 10mm long
10. Small, solid plasticine ball, approximately 20mm diameter

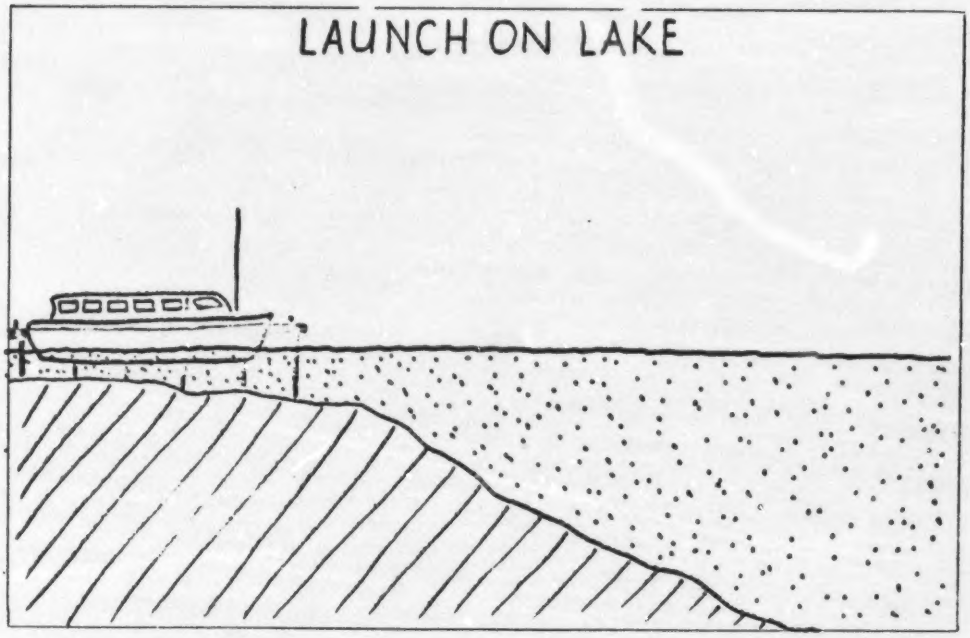
Bowl of water to test the materials in.

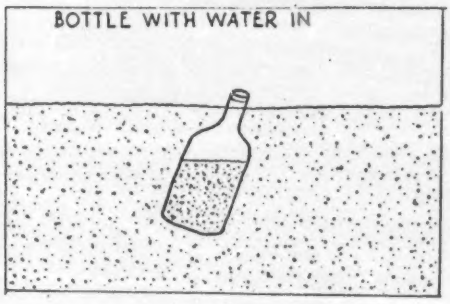
APPROACH USED:

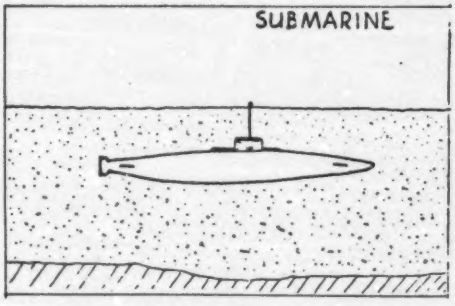
* Ask the children to put in one group the materials they think will float, and to put into another group those they think will not.
* Seek the children's reasons for why they put the various materials in either the group of 'floaters' or 'non-floaters'.
* Have the children test the materials in the bowl of water.
* Seek the children's reasons for why they think the various materials behave as they do in the water.
* With the materials grouped into 'floaters' and 'non-floaters' based on observation of their behaviour in the water, ask the children if they can think of one reason why the materials either floated or sank.

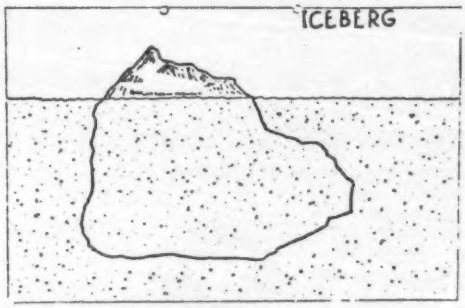
APPENDIX 3: Cards and materials used for survey.

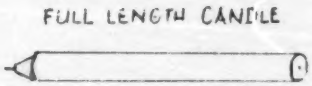
Each card was A.4 size.

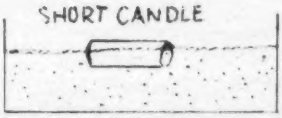












APPENDIX 4: Stimuli used to enable children at the S3-F1 level to generate questions and explanations about floating and sinking.

1. Stimuli used the researcher

The children were told that they would be shown several things and then invited to ask questions. In turn they were invited to speculate about and then observe a plastic lid, golf ball and metal paper clip being dropped into a clear container of water. They were then reminded that although the small paper clip sank, huge steel ships float.

2. Stimuli used by two teachers

In one case the children were read a short book on the topic 'Floating and Sinking' by their teacher. In the other they were given an opportunity to test various materials and objects (e.g. tennis ball, plastic lid, piece of pumice, branch, plastic icecream container, tin with lid off) in the school swimming pool.

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